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DATA REPORT FOR THE 1995 WIND RIVER MOUNTAINS - GREEN RIVER BASIN SEISMIC REFRACTION PROFILE

Stephan H. Koester
John J. Cipar

23 May 1996

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PHILLIPS LABORATORY
Directorate of Geophysics
AIR FORCE MATERIEL COMMAND
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ERRATA

On page 1, the title reads, The 1995 Wind River Mountains - Green River Basin, Wyoming, Seismic Refraction Profile. It should read, Data Report for the 1995 Wind River Mountains - Green River Basin, Wyoming, Seismic Refraction Profile

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13. ABSTRACT *(Maximum 200 words)*

During August, 1995, the Earth Sciences Division of Phillips Laboratory (PL/GPE) recorded a seismic refraction profile across the Wind River Mountains and adjacent Green River Basin using controlled explosions fired east of Lander, Wyoming, as part of the Deep Probe experiment. The Deep Probe Experiment was an ultra-large scale active seismic profile carried out by several US and Canadian universities and the Canadian Geological Survey with the goal of imaging the upper mantle of western North America. The main Deep Probe profile was oriented north-south from Edmonton, Alberta, to Crownpoint, New Mexico, a distance of 1900 km. An intermediate shot point was located approximately 50 km east of Lander, Wyoming, and provided the sources for the seismic profile described in this report The PL/GPE profile consisted of 47 shot-station points extending from Big Sandy, Wyoming, west to the Idaho-Wyoming border, a distance of 150 km.

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The 1995 Wind River Mountains - Green River Basin, Wyoming, Seismic Refraction Profile

1. INTRODUCTION

During the summer of 1995, the Earth Sciences Division of Phillips Laboratory (PL/GPE) undertook an extensive seismic experiment in southwestern Wyoming. The experiment had two parts: (a) recording a seismic refraction profile across the Green River Basin using explosions fired east of Lander, Wyoming as part of the Deep Probe experiment; and (b) installation and operation of a large-aperture array during August and September. A description of the technical aspects of the refraction profile is the subject of this first report; a separate report covers data recorded by the large-aperture array.

In August, 1995, several US and Canadian universities along with the Canadian Geological Survey performed the Deep Probe Experiment, an ultra-large scale active seismic experiment in western North America (Henstock et al, 1995). The main Deep Probe profile was oriented north-south from Edmonton, Alberta, to Crownpoint, New Mexico, a distance of 1900 km. An intermediate shot point was located approximately 50 km east of Lander, Wyoming, and provided the sources for the Wind River Mountains - Green River Basin Seismic Refraction Profile described in this report. This profile consisted of 47 shot-station points extending from Big Sandy, Wyoming, west to the Idaho-Wyoming border, a distance of about 150 km (Koester et al., 1995).

We plan to use the data from this experiment to study:

- regional wave propagation in the central Rocky Mountains
- spatial variability of earthquake/explosion discriminants
- crustal structure beneath the Wind River Mountains and Green River Basin

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2. PREVIOUS GEOPHYSICAL WORK

The Green River Basin is an extensive Cenozoic sedimentary basin bounded by the Precambrian Wind River Mountains on the east, the Wyoming Range on the west, and the Uinta Mountains of Utah to the south. The southern part of the basin contains the Mesozoic Rock Springs uplift. While the underlying rocks are of various ages, the overall structure of mountain bounded basin was formed during the late Cretaceous-early Tertiary Laramide orogeny. The Wind River Mountains are a thrust-faulted basement anticline that overrode the eastern part of the Green River basin (Smithson et al., 1979).

The Green River basin abuts the eastern edge of the Intermountain Seismic Belt; there is considerable seismicity to the south and west of the basin (Pechmann et al, 1995). Previous geophysical studies include a seismic refraction profile from American Falls Reservoir, Idaho, to Flaming Gorge Reservoir, Wyoming, with an intermediate shot point at Bear Lake, Idaho-Utah (Prohdel, 1979). Pechmann et al (1995) used the Prohdel (1979) P-wave velocity-depth model to infer S-wave velocities and densities. This model has a crustal thickness of 40 km and is underlain by 7.9 km/s mantle material. Braile et al (1974) interpreted a single-ended refraction profile extending from the Bingham Canyon copper mine near Salt Lake City, Utah, across the Green River Basin to the Wind River Mountains. They infer that the crustal thickness is 40 km or greater beneath the Green River Basin and southern Rocky Mountains. Smithson et al (1979) and Brewer et al (1980) discuss COCORP deep seismic reflection data collected across the southern end of the Wind River Mountains and adjacent Green River and Wind River Basins. These observations indicate the shallow overthrust nature of the Wind River Mountains.

3. THE WIND RIVER MOUNTAINS - GREEN RIVER BASIN SEISMIC REFRACTION PROFILE

The Wind River Mountains - Green River Basin Seismic Refraction Profile was deployed during the Deep Probe project of August 1995 to image the crustal structure beneath the Wind River Mountains and the Green River Basin. Unlike the Deep Probe profiles, the Wind River Mountains - Green River Basin Seismic Refraction Profile was oriented east-west. The refraction profile begins on the west side of the Wind River Mountains, 135 km from the quarry, and extends in the general azimuth of 265° across the Green River Basin and the Wyoming Range to a total distance of about 280 km from the quarry (Figure 1). A total of 47 stations were installed, spaced approximately 3.2 km apart from each other.

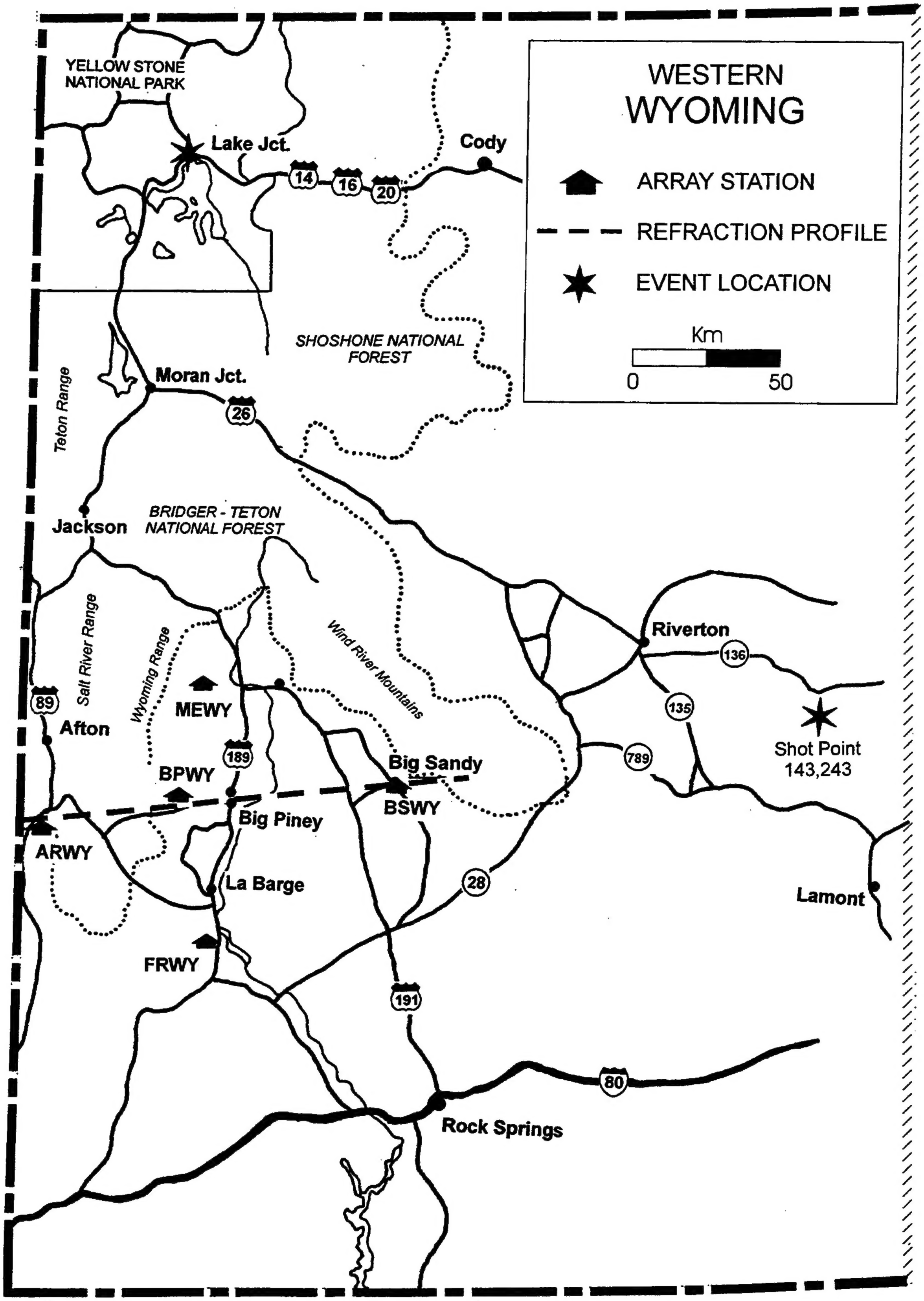


Figure 1. Location Map. The Green River refraction profile is shown by the heavy dashed line. The Wyoming shot points are denoted by the star SE of Riverton. The profile was selected to take advantage of large-aperture array stations (house symbol). Dotted lines indicate approximate location of the Wind River and Wyoming Range Mountains

The refraction study utilized two Deep Probe explosions east of Lander, Wyoming, as its energy source. The first explosion (labeled 143) was about 15,000 lbs. of ammonium nitrate/fuel oil (ANFO) detonated on the bottom of a water filled quarry (G. R. Keller personal communication). The second explosion (labeled 243) was fired one week later with approximately the same amount of ANFO about 650 feet from the first explosion (Table 1). The large source size and excellent coupling in the quarry provided exceptional signal-to-noise ratios across the profile.

Table 1. Shot Locations

Shot#	Date	Time (GMT)	Latitude	Longitude	Elev. (m)[1]	Depth (m)[2]
143	08-09-95	11:30:00.000	42.731 N	107.667 W	1958.0	46.0
243	08-17-95	11:30:00.000	42.730 N	107.665 W	1958.0	46.0

[1]Elevation refers to quarry water level relative to sea level.
[2]Depth refers to distance between quarry water level and quarry bottom where the ANFO was detonated.

3.1 Installation and Instrumentation of the Profile

Three different types of portable stations were deployed along the profile (Table 2). Figure 2 shows the basic setup of a refraction profile station. The particular station setup displayed uses RefTek and GeoSpace instruments, but can also be used as a general guideline for every station configuration used in the profile. Common to each configuration is a seismometer buried about one foot deep, a data acquisition recorder, a power supply, and a timing system.

The first configuration consisted of 3-component, 1.0 Hz GeoSpace HS-10-1b seismometers recorded and digitized by a 24 bit Refraction Technology data acquisition system (DAS). The DAS contained a hard disk drive to store the digitized signal and was powered by two 12v gel cells. A global positioning satellite (GPS) clock was connected to the DAS to provide accurate timing and geographic location. The DAS was set up to record a continuous single data stream at 100 samples per second consisting of 3 data channels at 24 bit resolution with a preamplifier gain of 32. The nominal sensitivity of the HS-10-1b seismometer is 600 v/m/sec.

Table 2. Station Locations

Station # Available	Latitude	Longitude	Z (m)	Recorder	# of Channels	Data
1	42 32.09 N	109 12.54 W	2450	TerraTek	1	No
2	42 33.84 N	109 14.85 W	2425	TerraTek	1	No
3	42 34.20 N	109 17.14 W	2430	TerraTek	1	Yes
4	42 33.13 N	109 19.45 W	2350	TerraTek	1	Yes
5	42 33.58 N	109 21.80 W	2200	TerraTek	1	No
6	42 36.73 N	109 24.11 W	2250	PDAS	3	Yes
7	42 37.32 N	109 26.36 W	2250	TerraTek	1	Yes
8	42 36.67 N	109 28.70 W	2190	TerraTek	1	Yes
9	42 36.92 N	109 31.13 W	2180	PDAS	3	Yes
10	42 35.42 N	109 33.50 W	2200	PDAS	3	Yes
11	42 33.65 N	109 35.78 W	2215	PDAS	3	Yes
12	42 36.22 N	109 38.20 W	2200	PDAS	3	Yes
13	42 36.05 N	109 40.57 W	2210	PDAS	3	Yes
14	42 36.17 N	109 42.88 W	2200	PDAS	3	Yes
15	42 36.33 N	109 45.22 W	2150	PDAS	3	Yes
16	42 35.95 N	109 48.64 W	2120	PDAS	3	Yes
17	42 36.07 N	109 49.97 W	2100	PDAS	3	Yes
18	42 35.99 N	109 52.18 W	2100	PDAS	3	Yes
19	42 35.44 N	109 54.54 W	2100	PDAS	3	Yes
20	42 33.95 N	109 56.90 W	2110	PDAS	3	Yes
21	42 34.68 N	109 59.27 W	2110	PDAS	3	Yes
22	42 34.67 N	110 01.53 W	2120	PDAS	3	Yes
23	42 34.80 N	110 03.20 W	2110	PDAS	3	Yes
24	42 34.07 N	110 06.24 W	2100	PDAS	3	Yes
25	42 32.67 N	110 08.59 W	2100	PDAS	3	Yes
26	42 32.59 N	110 10.96 W	2125	PDAS	3	Yes
27	42 32.44 N	110 13.28 W	2150	PDAS	3	Yes
28	42 32.37 N	110 15.62 W	2190	RefTek	3	Yes
29	42 32.44 N	110 18.01 W	2250	RefTek	3	Yes
30	42 31.92 N	110 20.35 W	2250	RefTek	3	Yes
31	42 31.56 N	110 22.75 W	2300	RefTek	3	Yes
32	42 31.61 N	110 24.99 W	2300	RefTek	3	No
33	42 30.71 N	110 28.60 W	2380	RefTek	3	Yes
34	42 30.71 N	110 28.60 W	2380	RefTek	3	Yes
35	42 30.48 N	110 31.03 W	2450	TerraTek	1	Yes
36	42 28.92 N	110 33.06 W	2500	RefTek	3	Yes
37	42 27.50 N	110 35.29 W	2500	TerraTek	1	No
38	42 28.82 N	110 37.50 W	2500	RefTek	3	Yes
39	42 30.29 N	110 40.34 W	2600	TerraTek	1	No

Table 2. (Continued)

40	42 31.68 N	110 42.20 W	2650	RefTek	3	No
41	42 31.63 N	110 44.65 W	2450	TerraTek	1	Yes
42	42 29.69 N	110 48.12 W	2350	RefTek	3	Yes
43	42 29.38 N	110 50.50 W	2300	TerraTek	1	No
44	42 30.61 N	110 53.05 W	2250	RefTek	3	Yes
45	42 29.17 N	110 55.12 W	2150	TerraTek	1	Yes
46	42 23.99 N	111 00.46 W	1950	RefTek	3	Yes
47	42 24.14 N	111 02.70 W	1950	TerraTek	1	Yes
Merna Jct	42 56.34 N	110 20.79 W	2340	RefTek	3	Yes
Big Sandy	42 37.91 N	109 28.04 W	2200	RefTek	3	Yes
Big Piney	42 32.06 N	110 16.53 W	2250	RefTek	3	Yes
Fontenelle	42 05.44 N	110 10.06 W	2000	RefTek	3	Yes
Allred	42 29.55 N	110 57.74 W	1900	RefTek	3	Yes

The second station configuration deployed along the profile included a single vertical component 1.0 Hz GeoSpace HS-10/1b seismometer digitized by a Terra Technology recorder with WWVB radio timing. The Terra Technology recorders used an alarm clock to start data acquisition before the anticipated chemical explosion. Once triggered, the recorders acquired data for about 10 to 15 minutes and stored the data onto a cassette tape. The Terra Technology recorders were set to record one data channel with 12 bit resolution using a static gain of either 100 or 1000 at 100 samples per second.

The final station configuration consisted of 1.0 Hz MARK-L-4C-3D geophones recorded and digitized by a Teledyne Brown Engineering Portable Data Acquisition System (PDAS). The PDAS used GPS for both timing and geographic location. The PDAS system was configured to record for 15 minutes starting at the shot origin time. The parameters were set to acquire 3 data channels at 14/2 bit resolution with a preamplifier gain of 1 at 100 samples per second. The PDAS data was later resampled at 125 samples per second to conform to other Deep Probe data sets.

In addition, data from three large aperture array stations are included in the data set. These stations are spaced approximately 50 km from each other in nearly a straight line and are located in the same azimuth as the refraction profile.

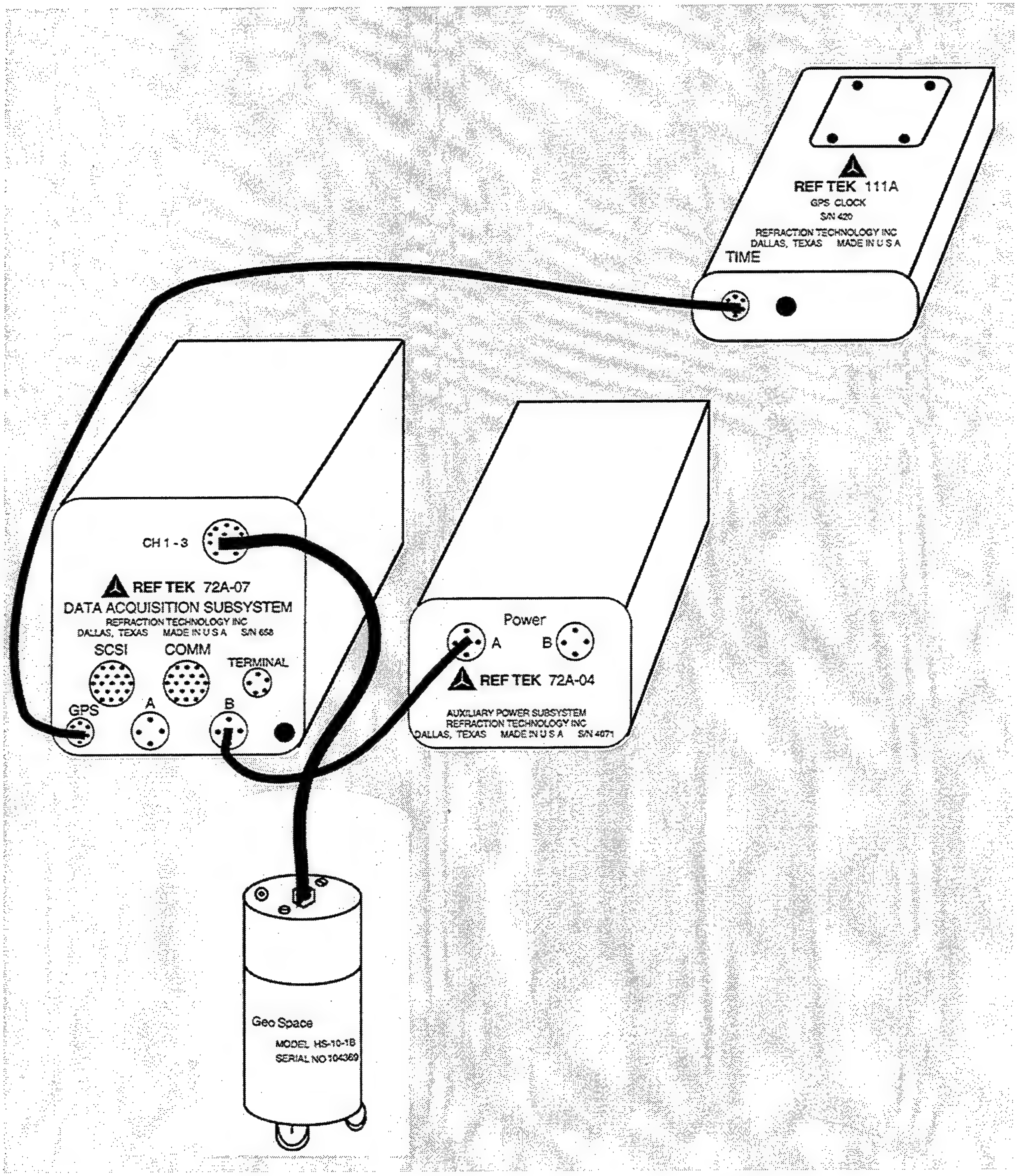


Figure 2. Refraction Station Schematic. Stations consisted of sensor, recorder, battery power, and timing system. The arrangement for a Refraction Technology recorder station is shown here.

3.2 Operation of Profile

The profile was deployed in two stages to increase the offset from the shot point. Since the two chemical explosions were at the same location, all of the instruments were re-deployed to different locations along the profile resulting in a longer and denser profile. The first deployment occurred on August 8th, one day before the first ANFO detonation. Fourteen stations were installed for this deployment. Seven stations were equipped with RefTek recorder configurations and seven stations were equipped Terra Technology recorder configurations. The deployment of stations began at the entrance to the Bridger National Forest with a Refraction Technology recorder configuration, continued through the national forest alternating recorder configurations, and ended at the border of Wyoming and Idaho with a Terra Technology recorder configuration. The stations were removed the following day (August 9th) in the reverse order in which they were deployed. Thus, the stations that were retrieved first include less data than those retrieved last.

The second deployment occurred on August 16th, one day before the second explosion. Thirty-three stations were deployed including Refraction Technology, Terra Technology and PDAS recording configurations. The second deployment stretched from the edge of the Wind River Mountains west to the entrance of the Bridger National Forest. The stations were removed the following day, on August 17th.

Stations were located along existing roads, which necessitated several jogs of up to 3 km from the profile azimuth. A vehicle odometer was used to deploy the stations, then the latitude and longitude were measured using a hand-held GPS receiver. The final geographic locations listed in Table 2 are obtained by taking multiple RefTek GPS locations at each site. Individual GPS locations not within the L1 - sigma of the median location at each site were discarded. The remaining GPS locations were averaged to give a final location. Final geographic locations for sites that either did not have a RefTek GPS installed, or did not receive more than 5 RefTek GPS locations, were picked off a USGS 30X60 minute quadrangle map. At each station, the sensors were placed in shallow holes, leveled and then covered to reduce wind noise. The recording instruments were placed several feet from the sensors and were then sheltered from the sun by using garbage bags and vegetation cover to avoid over-heating.

3.3 Profile Data

The data from both Wyoming Deep Probe explosions have been combined to form a seismic profile that extends from about 134 km to 280 km from the source (Figure 3). The whole profile displays exceptionally high signal-to-noise ratios due to the large source size and excellent coupling

Green River

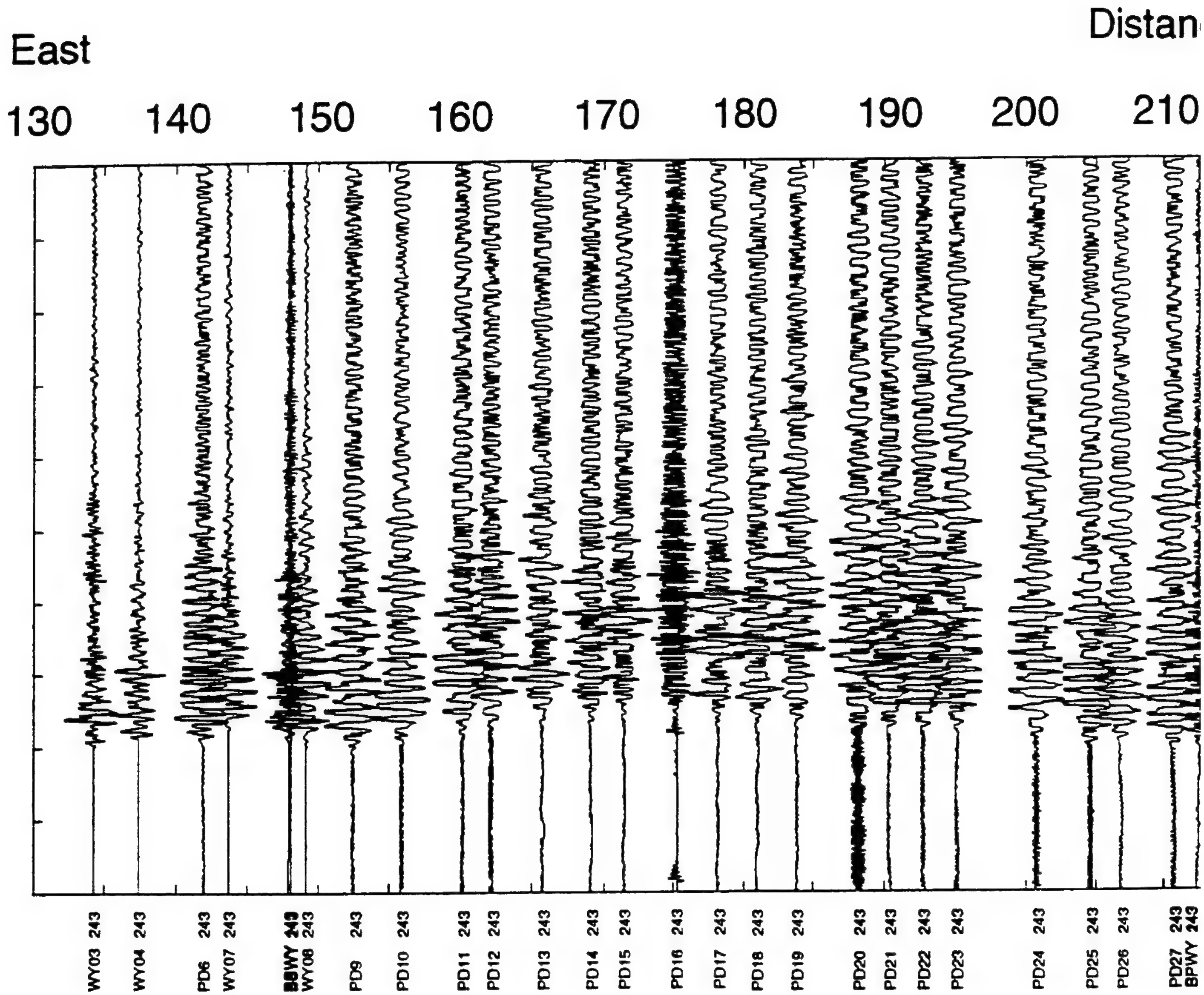


Figure 3. Green River
record section. Data i
are displayed in trace
section format reduce
East (Big Sandy) is to
side is at the Idaho-W

1

Green River Seismic Profile

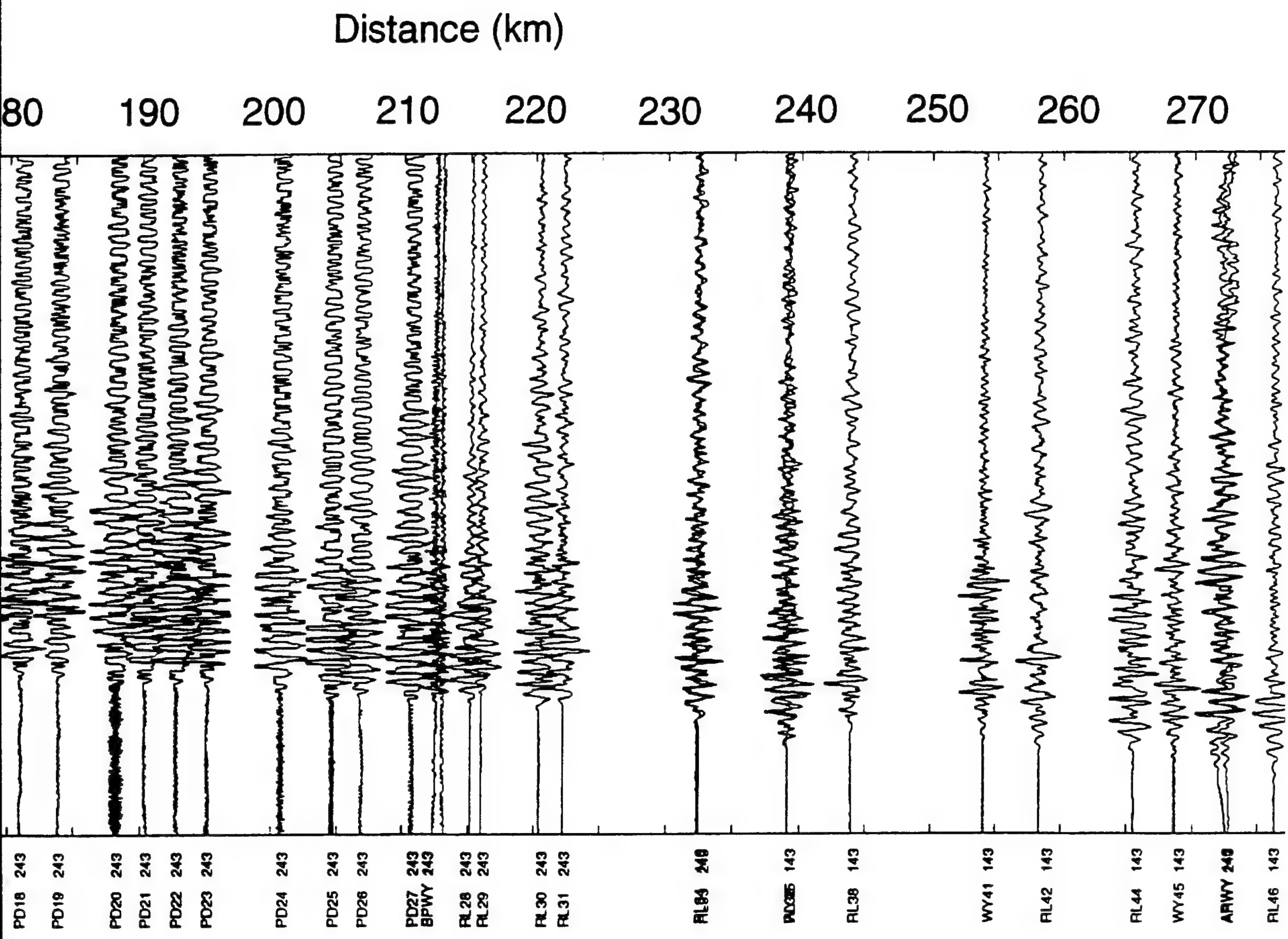
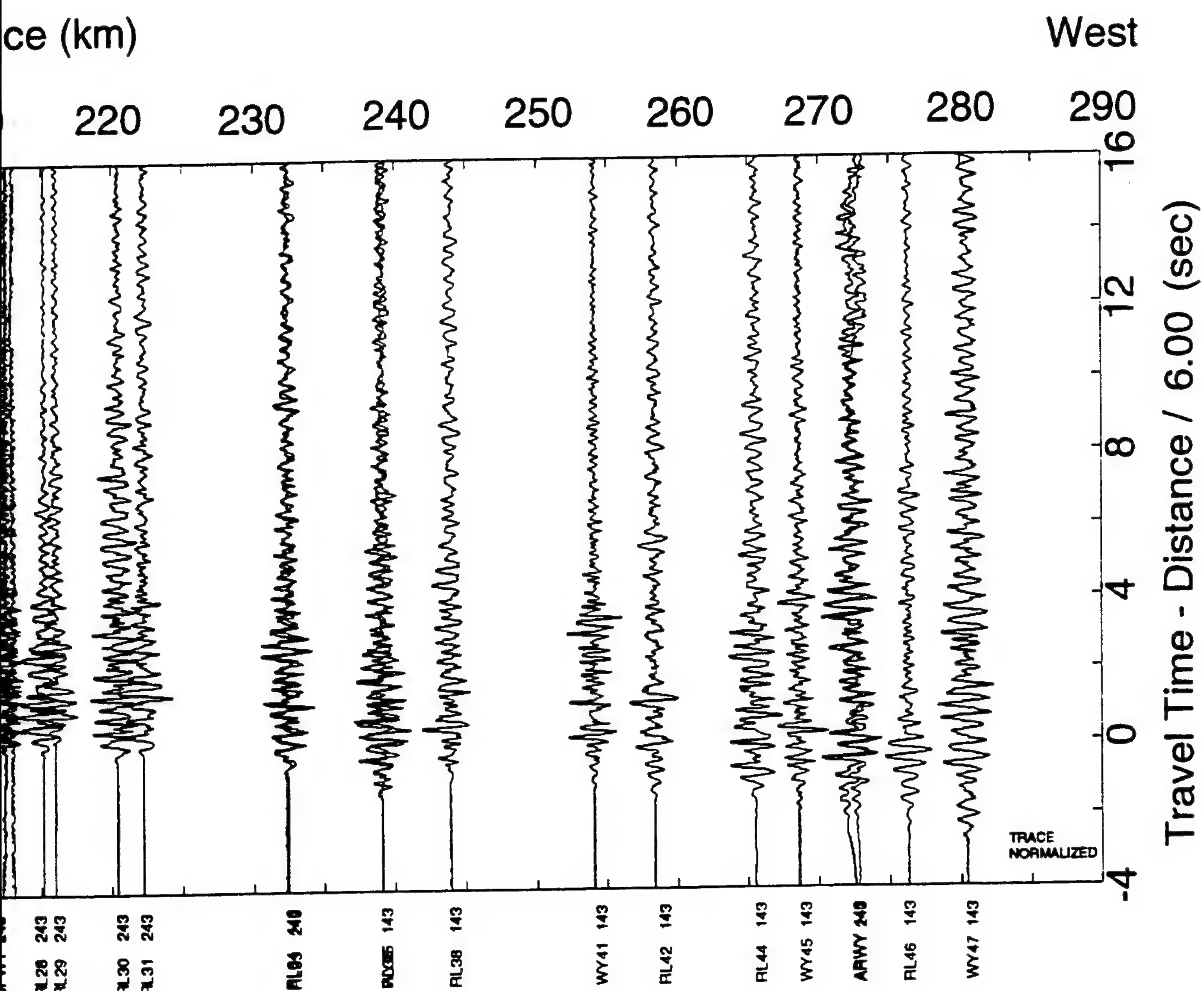


Figure 3. Green River Seismic Profile record section. Data from both shots are displayed in trace normalized record section format reduced at 6 km/sec. East (Big Sandy) is to the left; the right side is at the Idaho-Wyoming border.

2

Seismic Profile



Seismic Profile
from both shots
normalized record
d at 6 km/sec.
the left; the right
/yoming border.

in the quarry. Unfortunately, other Deep Probe shots outside Wyoming were of only marginal quality in our data and are not shown. The complete profile data set is currently archived in SAC format on Exabyte tape and is currently available from us at Phillips Laboratory. We intend to archive the data at the IRIS Data Management Center at a later date.

The Wind River Mountains - Green River Basin Seismic Refraction Profile can be used for a variety of seismic studies due to similar source properties of both blasts. We verified the similarity of both sources by comparing seismograms from each shot recorded at the same location. Stations 33 and 34 (Table 2) were occupied for the first and second blast, respectively. Both stations are at the same location and both were equipped with Refraction Technology recorders and HS-10 seismometers. Figure 4a shows time domain traces from the two blasts. The only obvious difference is the peak at 108 seconds in blast #1 (upper panel) which is not evident in blast #2 (lower panel). Otherwise, the two waveforms are relatively similar. To more accurately determine the differences between the two blasts, spectral amplitudes of the entire blast, the P-wave, and a pre-event ambient noise sample are examined (Figures 4b - 4d). Figure 4b shows the spectral amplitudes of a 6-minute window around the blasts. The energy of both blasts is predominantly in the 1.0 - 8.0 Hz frequency band. Within this frequency band, the blasts contain different spectral amplitude peaks. The most notable is that blast #1 (upper panel) contains a higher amplitude peak at 1.0 Hz while blast #2 (lower panel) contains a higher peak at 6.0 Hz. Figure 4c examines the spectral amplitudes of only the P-wave. In this figure, blast #2 displays more prominent peaks at 3.0 and 7.0 Hz, while blast #1 shows a peak at around 4.5 Hz. Figure 4d displays the spectral amplitudes of a 50-second pre-event noise sample. Most of the noise occurs between 0.0 and 1.0 Hz (which is not within the 1.0 - 8.0 Hz frequency band in which the seismic signal resides). In addition, the seismic noise is also an order of magnitude smaller in amplitude than the seismic signal. The preliminary spectral study confirms that although the seismic signals are not identical, the signals from both blasts have enough similarity to justify combining both data sets for this refraction study.

4. FUTURE WORK

This report documents the Wind River Mountains - Green River Basin Seismic Refraction Profile data set using 2 large chemical explosions east of Lander, Wyoming as the source. The chemical explosions were recorded across the Wind River Mountains and Green River Basin of southwestern Wyoming. We plan to use this data set to constrain the crustal model for the region using one and two-dimensional travel time and waveform modeling. Finally, the seismograms will be archived for use by other investigators.

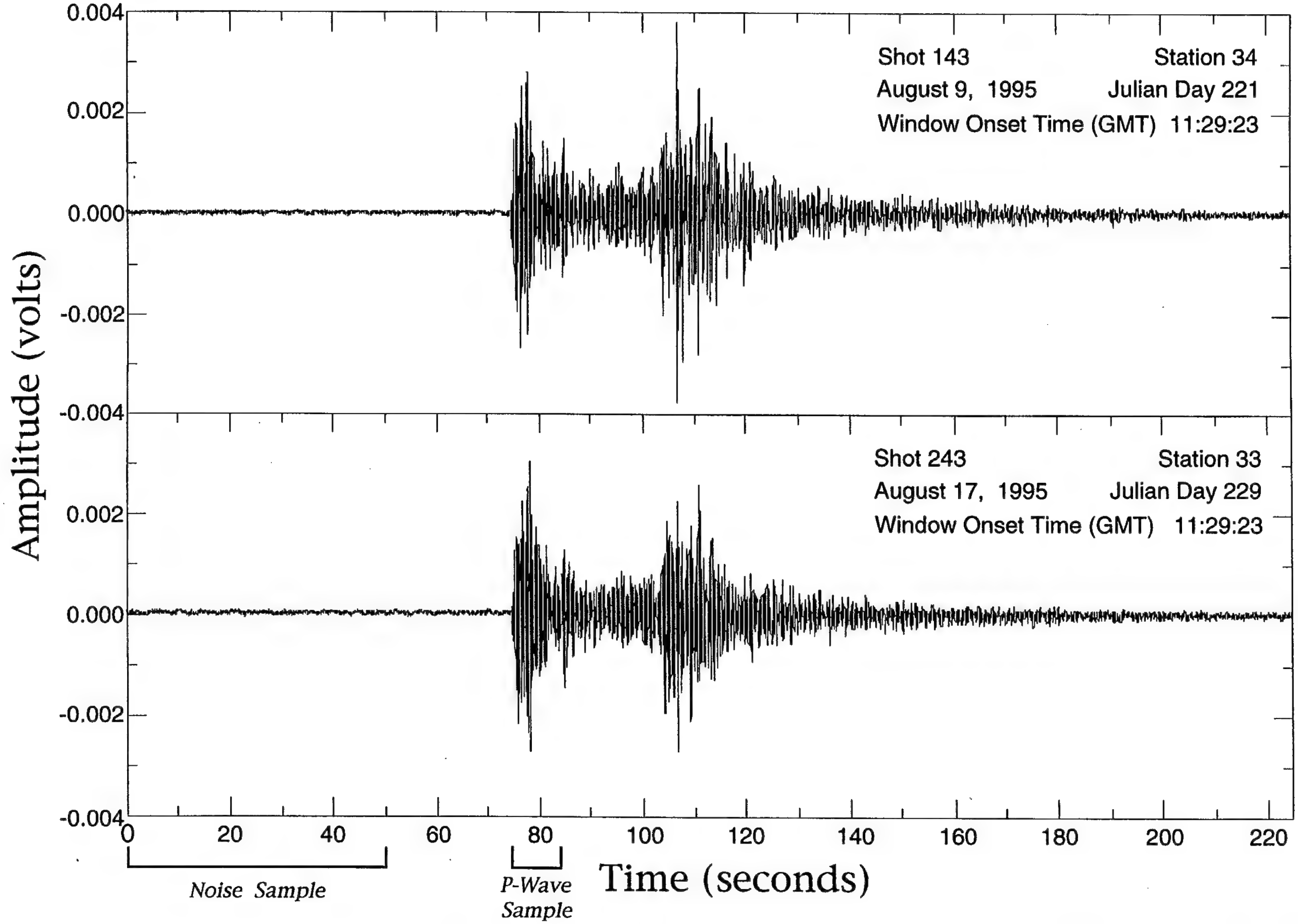


Figure 4a Seismograms from co-located stations for shot 143 (upper panel) and 243 (lower panel). Windows for noise and P-wave spectra are shown at bottom..

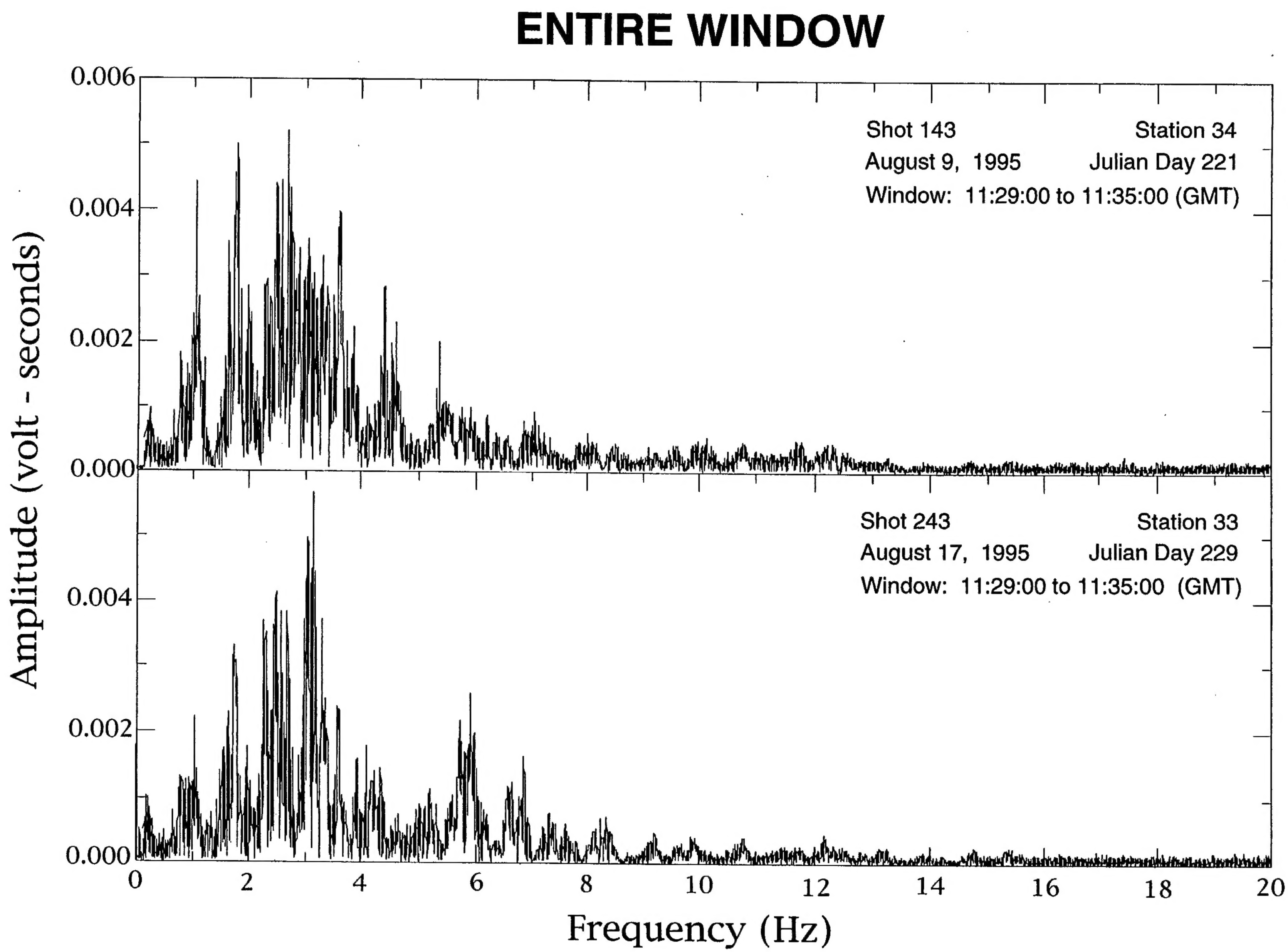


Figure 4b. Amplitude spectra for entire window shown in Fig. 4a. Most of the energy is between 0.5 and 8 Hz, although spectral peaks are different.

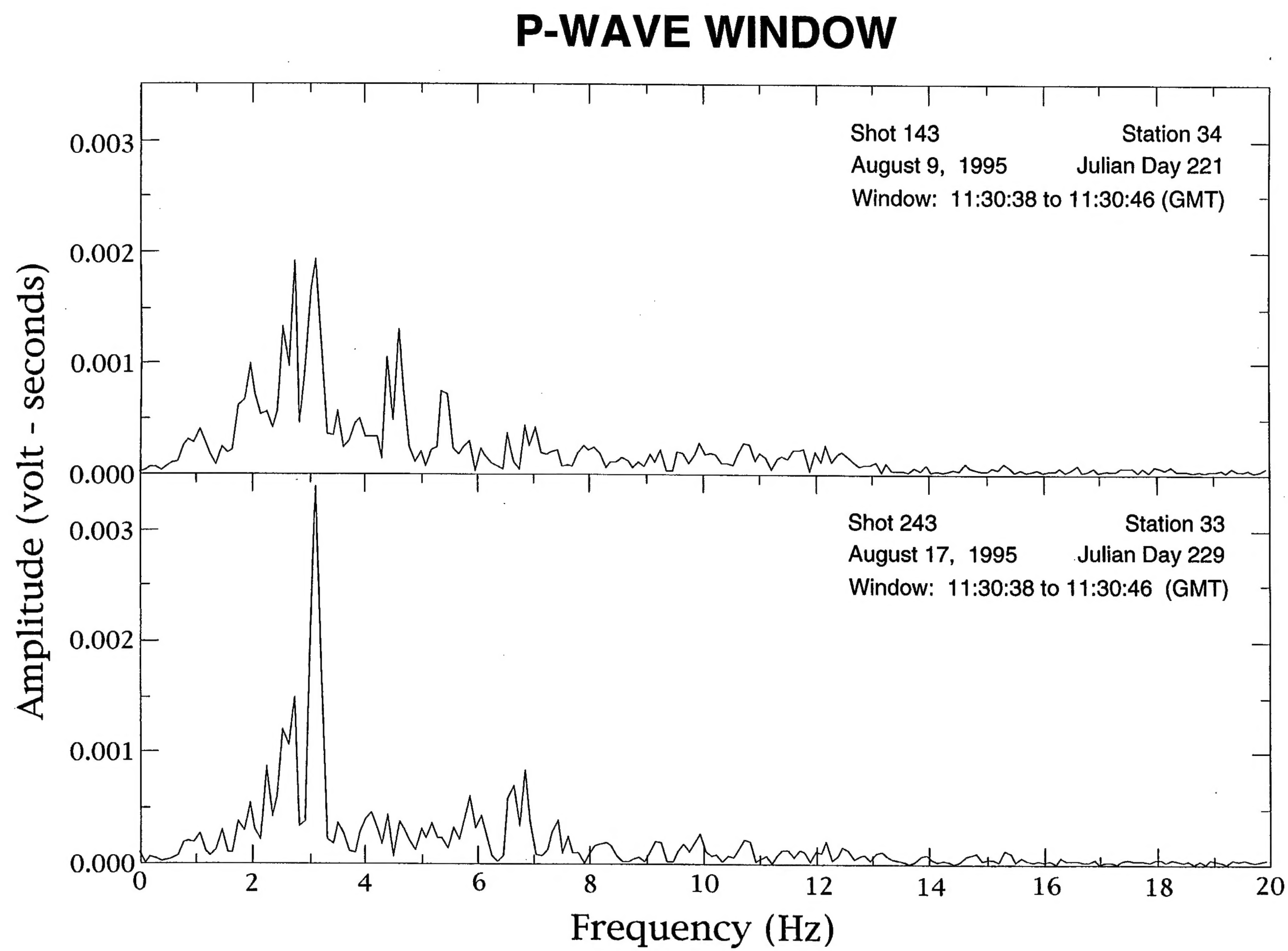


Figure 4c. Amplitude spectra for P-wave window (see Fig. 4a). Main peaks correlate in frequency, but not in amplitude. Note extra energy at ~ 5 Hz for shot 143

PRE-EVENT NOISE WINDOW

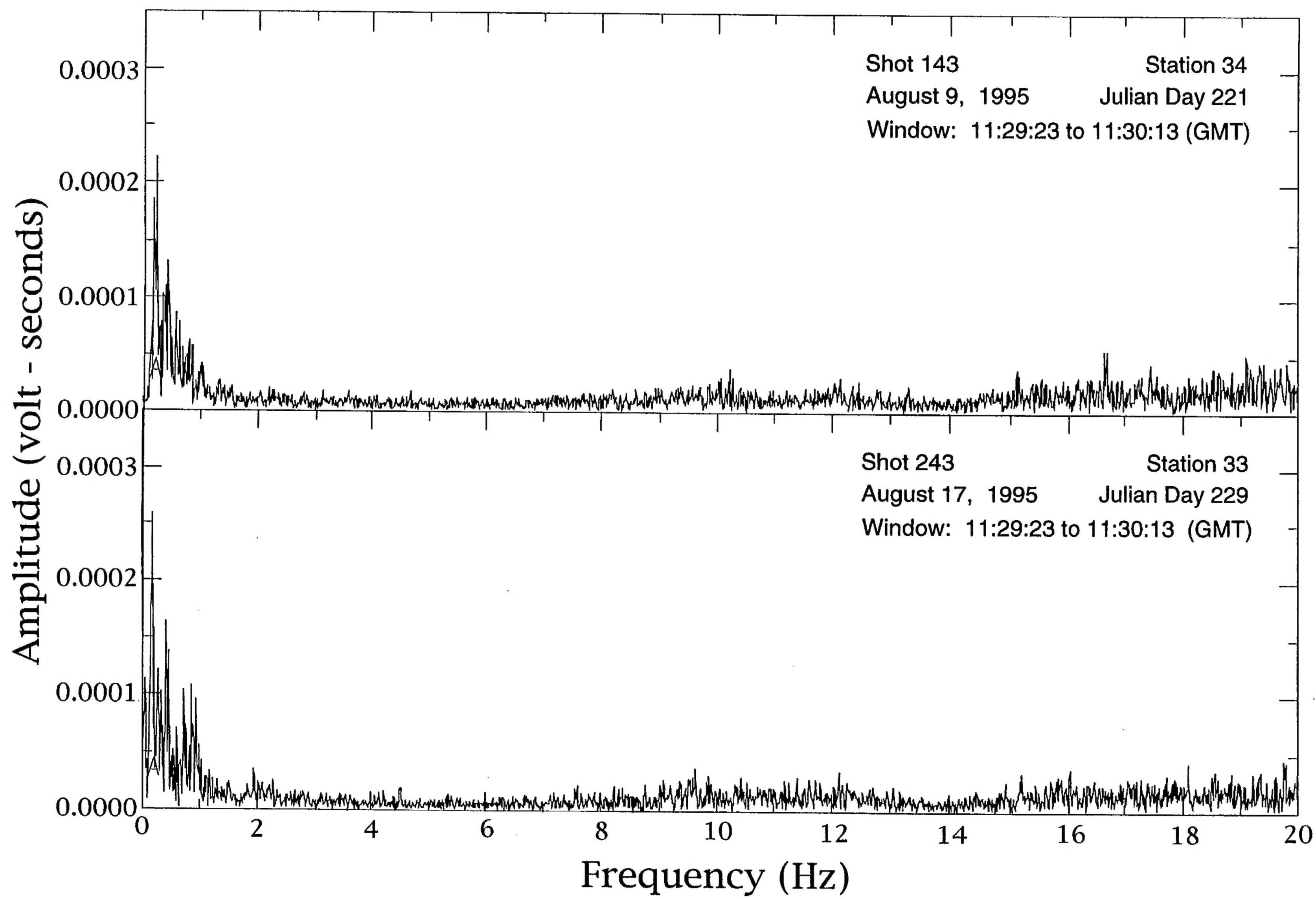


Figure 4d. Amplitude spectra for noise window (see Fig. 4a). Noise is predominantly below 1 Hz and is a factor of 200 less than the signal in the 2 - 4 Hz range.

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